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A Technique for Determining Apparent Selective Filtration in the Fresh-water Bivalve *Elliptio complanata* (Lightfoot)

by

COLIN G. PATERSON

Department of Biology, Mount Allison University,
Sackville, New Brunswick, Canada E0A 3C0

Abstract. *Elliptio complanata* (Lightfoot) filtering natural lake water shows a marked selectivity for smaller particles. Selection is for particle size rather than type as similar results were obtained when the bivalves were held in suspensions of animal charcoal. Filtration rate varies with particle abundance with the highest rates occurring at intermediate particle densities.

INTRODUCTION

AN EXTENSIVE literature exists on the filtration rates of marine bivalves as modified by a variety of extrinsic factors. Many of these studies have determined filtration rate from the rate of disappearance from the medium of organic and/or inorganic particles of a limited size range and of fixed abundance. Such determined values have only restricted applicability unless it is assumed that particle size and abundance do not modify apparent filtration rate. In contrast, numbers of authors have shown that measured filtration rate varies with particle size (VAHL, 1973; BAYNE *et al.,* 1977), abundance (RICE & SMITH, 1958; ALI, 1970; TENORE & DUNSTAN, 1973; FOSTER-SMITH, 1975; WIDDOWS *et al.,* 1979), and type (size?)(RICE & SMITH, 1958).

Studies on fresh-water unionid bivalves are sparse in comparison with those on marine species. ALLEN (1914), using *Lampsilis luteolus,* and DE BRUIN & DAVIDS (1970), using *Anodonta cygnea,* measured pumping rate by a direct method. SALANKI & LUKACSOVICS (1967) determined the rate of uptake of neutral red stain in *Anodonta cygnea.* Neither of these techniques is suitable for determining the effect of particle size, abundance, or type on filtration rate. LEWANDOWSKI & STANCZYKOWSKA (1975) used an indirect method to obtain limited results on filtration rates of *Anodonta piscinalis* and *Unio tumidus.*

The present study was undertaken to determine whether a species of fresh-water unionid bivalve, *Elliptio complanata* (Lightfoot), would show responses to variations in particle size, abundance, and type, as has been found in many marine species.

MATERIALS AND METHODS

During the summer months, specimens of *Elliptio complanata* were collected by dragging in Morice Lake, a relatively old (ca. 1765) polymictic, mesotrophic reservoir located approximately 3 km north of Sackville, New Brunswick, Canada. The collecting site is described in more detail by SEPHTON *et al.* (1980). At a shore laboratory, specimens were placed in a 55 × 115 cm polyethylene tank with an outlet drain located 30 cm above the bottom. Natural lake water was continuously pumped from an inlet located 20 cm above the lake bottom 15 m from the shore and supplied to the holding tank at a rate of 75 L/h. Aeration was continuous. Experiments were conducted in six plastic containers measuring 27.5 × 23.5 cm and having a depth of 14 cm. Containers were equipped with outlet valves 8.5 cm from the container bottom through which water samples were obtained. Six liters of freshly pumped lake water were added to each container. Five specimens of *E. complanata* with a maximum length of 6–7 cm were gently scrubbed and placed into each of four containers. The remaining containers served as controls.

At the initiation of the experiment, 50 mL water samples were removed through the outlet of each container and diluted 1:1 with an electrolyte solution; then, 2 mL samples were passed through a 200 μm aperture of a model TAII Coulter Counter equipped with a Population Mode. In all cases, triplicate particle counts were taken and averaged. This procedure was then repeated after 2 h. When a particle passes through the aperture it is counted as well as being assigned to one of 14 channels (channel

Table 1

Particle size distribution as monitored by the Coulter Counter using a 200 μm aperture.

Channel	Mean geometric volume (μm^3)	Minimum volume (μm^3)	Minimum diameter (μm)
3	47.39	33.51	4.00
4	94.78	67.02	5.04
5	189.6	134.0	6.35
6	379.1	268.1	8.00
7	758.3	536.2	10.08
8	1516	1072	12.70
9	3033	2145	16.00
10	6066	4289	20.20
11	12.13×10^3	8579	25.40
12	24.27×10^3	17.16×10^3	32.00
13	48.54×10^3	34.31×10^3	40.30
14	97.18×10^3	68.63×10^3	50.80
15	194.4×10^3	137.3×10^3	64.00
16	388.7×10^3	274.5×10^3	80.60

3 through channel 16) based on particle size. The mean geometric volume, minimum volume, and minimum diameter of the particles measured by each channel when a 200 μm aperture is used are given in Table 1. Because particle counts in channels 7 to 16 were too low to accurately determine filtration rate these particle counts were pooled. Background count due to the electrolyte solution was determined and suitable corrections made. Details on the application of the Coulter Counter to research of this nature may be found in SHELDON & PARSONS (1977), MAYZAUD & POULET (1978), POULET (1978), and HARBISON & MCALISTER (1979).

At the end of an experiment, the length (L) of each bivalve in a container was determined to the nearest 0.5 mm using calipers, and the individual dry tissue weight (W) was determined from the regression equation:

$$\log_{10} W \text{ (g)} = -2.403 + 2.770 \log_{10} L \text{ (cm)}$$

(CAMERON & *et al.,* 1979). Individual weights in each container were averaged and filtration rate determined as mL/g/h for this average weight using the formula:

$$\text{FR (mL/g/h)} = \frac{\log_e P_0 - \log_e(P_t^T + (P_0^c - P_t^c)) \times V \text{ (mL)}}{2 \times 5 \times \bar{W} \text{ (g)}}$$

where P = particles/mL, 0 = time 0, t = time 2 h, c = control, T = test, V = volume (mL), $\bar{W}$ = average dry tissue weight (g), and FR = filtration rate (mL/g/h).

Temperature was monitored in all experiments and ranged from a low of 19.0°C to a high of 22.7°C. No corrections have been attempted for these minor fluctuations. The containers were not aerated during the experiments as this would re-suspend pseudofaeces. This produces a possible error due to natural particle settling which is corrected for by determining the decline in the number of particles in each channel in the control containers.

This experimental approach was repeated on 18 occasions during the summer, and some variability in absolute filtration rates was observed which could have been a product of either fluctuations in particle abundance or in the nature of the particles. During August when the lake water remained at a relatively constant temperature of about 20°C, natural lake water was filtered through 3.0-μm Millipore filters and the filtrate used to make four dilutions of lake water. Two experiments were conducted each day. Each experiment consisted of two replicates of each of two of the particle densities and an appropriate control for each density. A total of eight replicates were determined for natural lake water and for each of the four dilutions. The sequence of replicates was staggered over the 10 days of the experiment in order to compensate for minor changes in particle concentration of the lake water during this period of time.

In an attempt to determine whether the apparent higher filtration rates observed for smaller particles was a product of reduced particle size or a result of the nature of the particles, further experiments were conducted in which technical animal charcoal was used to make a dense suspension in 3.0 μm filtered lake water. Amounts of suspension were added to containers of 6 L of 3.0 μm filtered lake water to produce a total particle count approximating 13,000 particles/mL. Five bivalves between 6 and 7 cm in length were added to each of four containers while the other two remained as controls. This experiment was replicated five times.

RESULTS

During the summer, filtration rate as determined from total particle counts or counts from specific channels showed little variation on any one day and often remained relatively constant over several days of stable weather. However, over the course of the summer, fluctuation in filtration rate did occur which might relate to seasonal or storm-induced changes in abundance and/or nature of the particles. When all data are pooled and the filtration rate in each channel changed to a percentage of the filtration rate calculated from channel 3 (Figure 1), a significant linear decline in relative filtration rate is found which can be adequately described by the equation: RFR = 176.8 − 23.95N ($n = 67$, $r = 0.89$, $P < 0.001$) where RFR is the relative filtration rate expressed as a percentage of that determined for channel 3 and N is the channel number. For the pooled 7–16 channels, channel 7 was used. The fitted line passes through the mean value for all channels except 3. That some curvilinearity exists between channels 3 and 4 is apparent from the intercept at channel 3, where the calculated RFR is 104.95%, although all observed filtration rates for this channel were set at 100%. As shown in Table 1, the mean geometric volume doubles

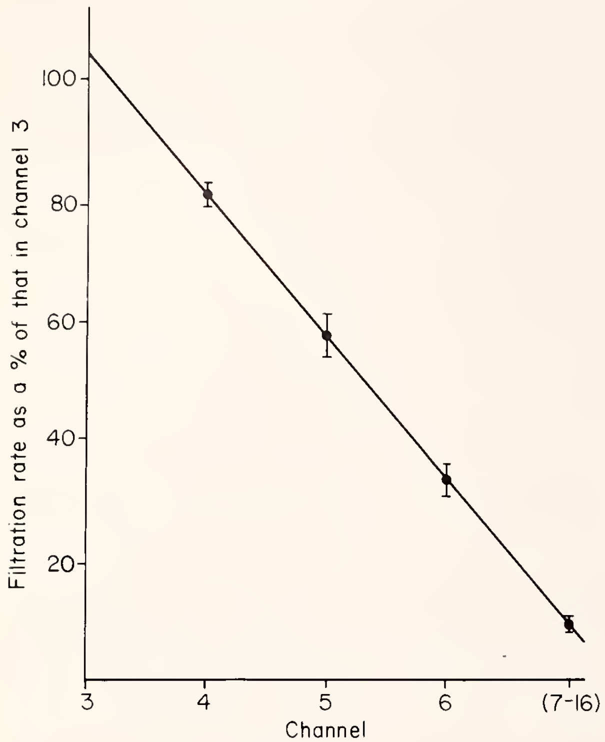

Figure 1

Elliptio complanata. Apparent filtration rate for each channel number expressed as a percentage of that determined for channel 3. Vertical bars represent one standard error about the mean.

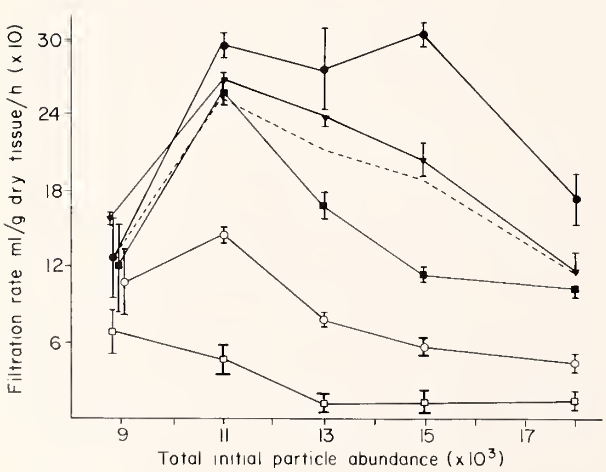

Figure 2

Elliptio complanata. Apparent filtration rates for total particle counts (dashed line), channel 3 (●), channel 4 (▼), channel 5 (■), channel 6 (○) and pooled results from channels 7 through 16 (□).

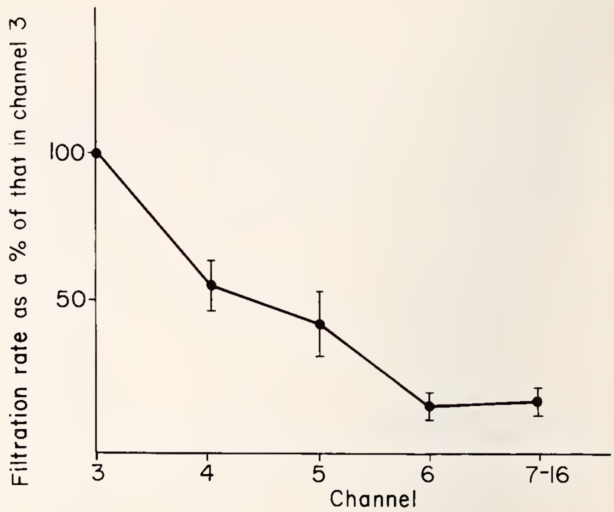

Figure 3

Elliptio complanata. Apparent filtration rates of technical animal charcoal expressed as a percentage of that determined for channel 3. Vertical bars represent one standard error about the mean.

from one channel to the next. Thus, a negative exponential decline in relative filtration rate occurs which is well described by the equation: $RFR = 230 - 76.3 \log_{10}V$, where V is the mean geometric volume for the channel. The number of particles in channel 7 is always substantially higher than in 8 through 16 so a mean geometric volume of 758.3 μm^3 was used for this channel group.

To test the possible effect of particle abundance on the variation observed over the summer, lake water collected over a limited time period was used to determine filtration rate in the unmodified water and in four dilutions (Figure 2). At the lowest seston concentration, all channels produced relatively similar filtration rate values. This might be brought about by a reduced pumping rate, which allows more time for successful filtration of the larger particles. An increase in average initial particle abundance to 11,000/mL caused a maximum filtration for most channels. Further increases in particle abundance resulted in a decline in the apparent filtration rate as calculated from particle uptake in all channels with the exception of channel 3. Filtration calculated for counts in this channel remained relatively constant over the particle range of 11,000–15,000/mL and then declined. The decreasing filtration rate with increasing channel number and, thus, particle size (Figures 1, 2) could result either from some active or passive "selection" operating on particle size as such or from selection on the nature of the particles. Figure 3 shows the results obtained when apparent filtration rate was determined using animal charcoal. A significant decline in apparent filtration rate occurs as the particle size increases from channel 3 through channel 6 and then remains constant.

DISCUSSION

The filtration activities of *Elliptio complanata,* at least as measured under summer conditions, show many patterns that are similar to those of marine filter-feeding bivalves. As found for marine forms by RICE & SMITH (1958), TENORE & DUNSTAN (1973), FOSTER-SMITH (1975), and WIDDOWS *et al.* (1979), filtration rate is lower at low particle concentrations and then increases to a peak value. After this peak is reached, there is then a decline as particles increase in abundance.

Like many marine bivalves (VAHL, 1973; BAYNE *et al.*, 1977), *Elliptio complanata* also appears to show pronounced selectivity. One obvious difference is that in the marine species selectivity appears to be for particles with equivalent spherical diameters between about 6 and 10 μm. In *Elliptio complanata* the selection is most definitely for the smaller particle sizes with the highest filtration rates normally being found for channel 3, which measures particles with diameters between 4.00 and 5.05 μm. The results of the studies using animal charcoal suggest that the selection is a passive one based on particle size and not particle nature. If selection is passive for a particular particle size, then it is interesting to interpret further the results found in this and other studies where filtration rate initially increases as particle abundance increases and then decreases. Results such as those presented in Figure 2 could be explained on the basis of either changes in the efficiency of particle retention or changes in actual pumping rate. Although both mechanisms may well be operational, it would appear that changes in pumping rate can at least partially explain the results. As shown in Figure 2, the apparent filtration rates at the lowest particle density were very similar for channels 3, 4, 5, and 6. At the highest particle densities, the filtration rates, as measured from these channel counts, began to approach some degree of similarity. It might well be that, at low particle density, water is pumped at a lower rate which allows more time for actual filtration and, consequently, particles of all sizes are retained efficiently. With an increase in particle abundance, pumping rate increases. At this increased rate, smaller particles are retained more effectively than larger particles. JORGENSEN (1983) has argued that, in marine filter feeders, an increase in the velocity of water passing over the gill mechanisms, which would result from an increased pumping rate, increases the efficiency of retention of smaller particles relative to larger ones. Perhaps when the particle density becomes great enough, there is no advantage in using energy to maintain an elevated pumping rate, as a much reduced pumping rate will still produce adequate food supplies.

It is apparent from the results of this study that the determination of an accurate measure of filtration rate is extremely difficult. To determine filtration activities of a species such as *Elliptio complanata,* it would be necessary to measure filtration in the natural seston suspensions of the habitat. The apparent filtration rate would have to be determined for essentially all particle sizes that the bivalve can effectively remove from the water. This would then allow determination of the total amount of material removed from the water in a given period of time. This study also would have to be expanded to cover the seasonal changes in the abundance and size distribution of the lake seston.

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